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(54) **HEATING DEVICE, FIXING DEVICE, AND
IMAGE FORMING APPARATUS**

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CPC **G03G 15/2053** (2013.01); **H05B 3/0014**
(2013.01); **H05B 3/06** (2013.01)

(58) **Field of Classification Search**

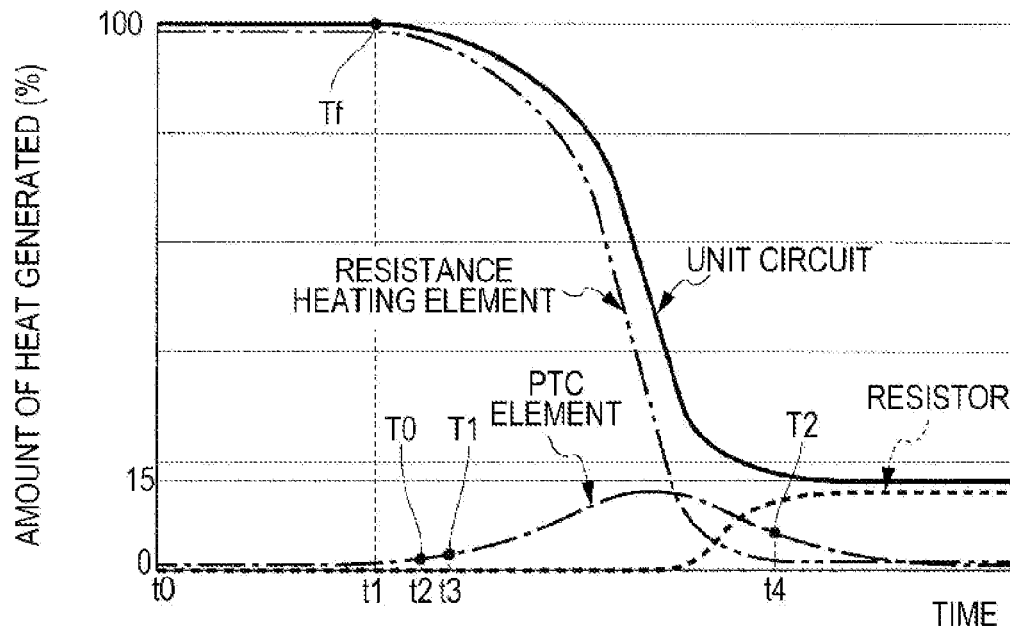
None

See application file for complete search history.

ABSTRACT

A heating device includes a rotating member that rotates, and plural unit circuits that are aligned in a width direction of the rotating member. The plural unit circuits each includes a heating body that heats the rotating member, a resistive element that is connected in series to the heating body and has a positive temperature coefficient, and a parallel circuit that is connected in parallel to the resistive element. The unit circuits are each configured such that, if a resistance value of the resistive element is increased with a rise of temperature of the resistive element, a current flows through the parallel circuit.

5 Claims, 11 Drawing Sheets



10

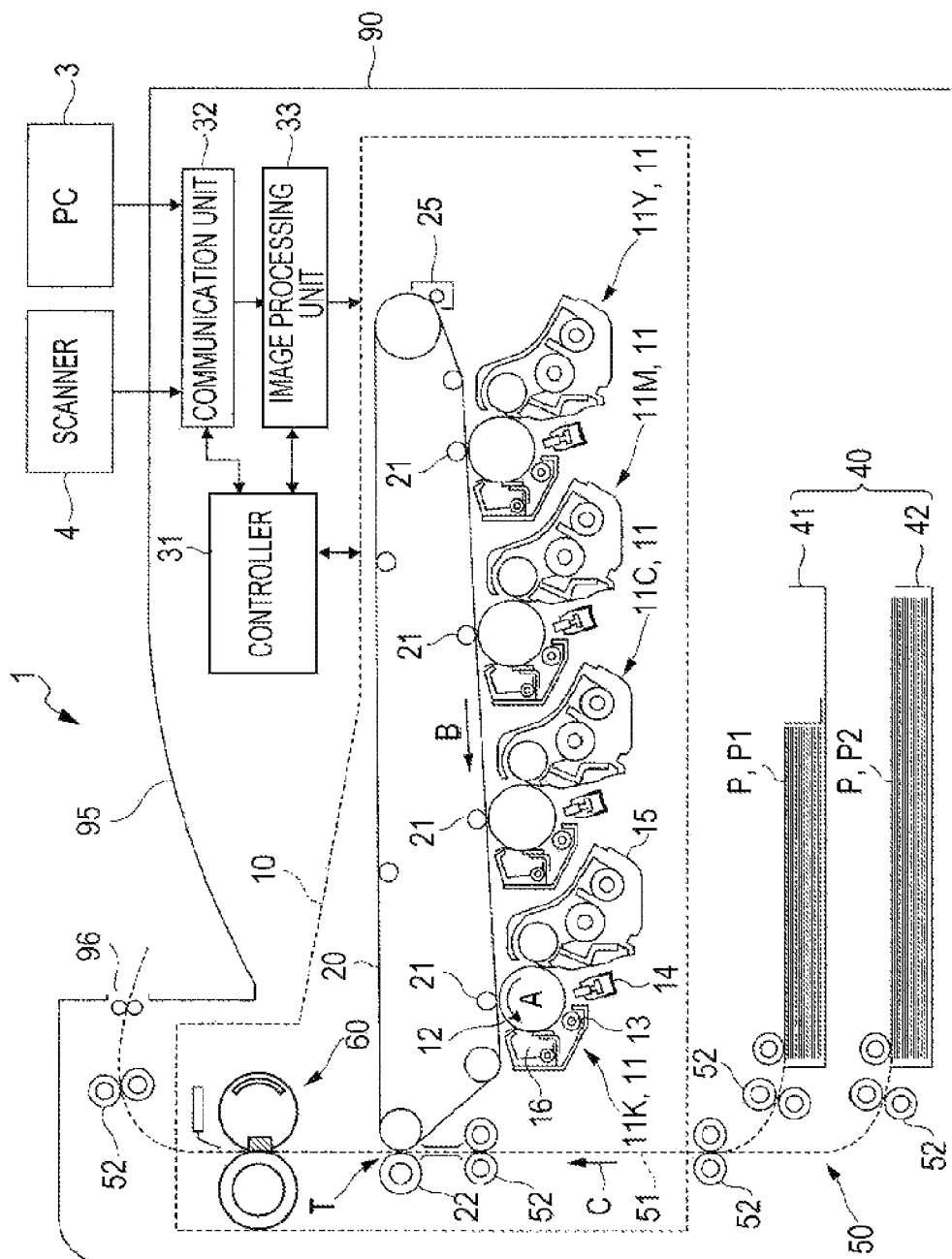


FIG. 2

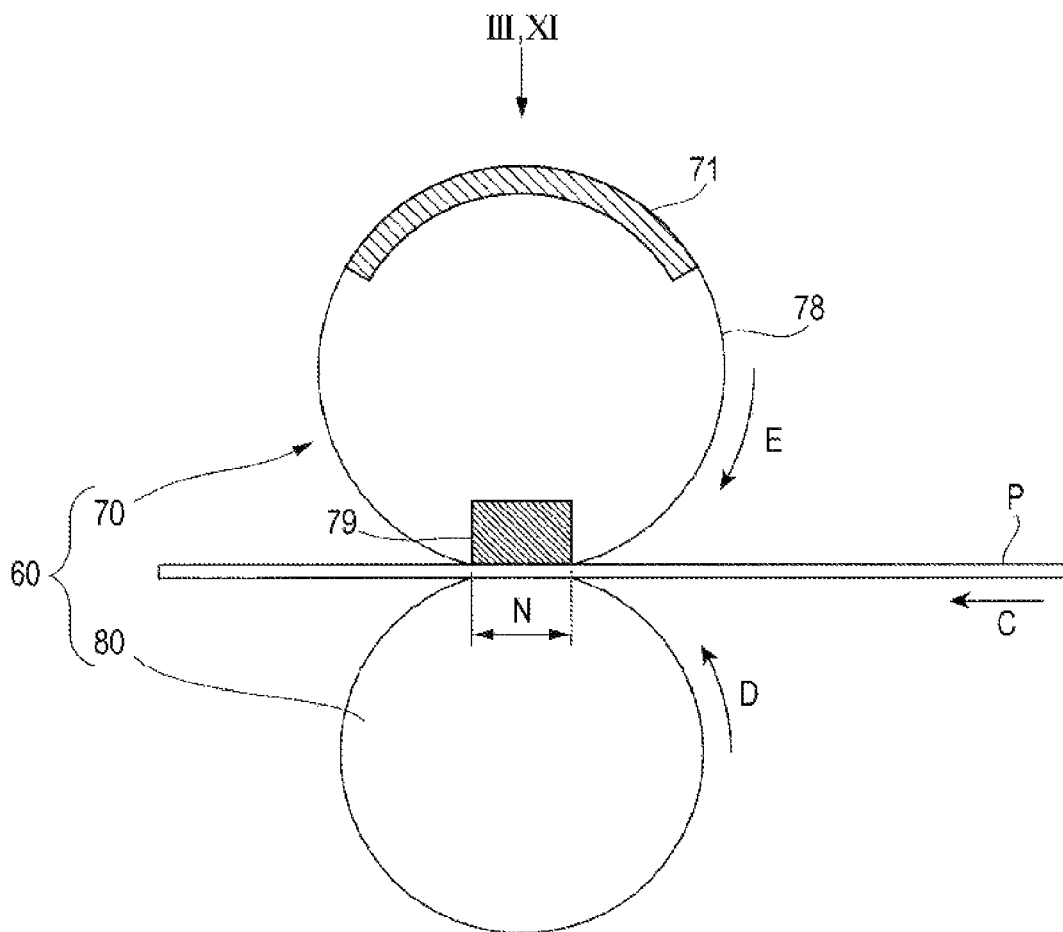


FIG. 3

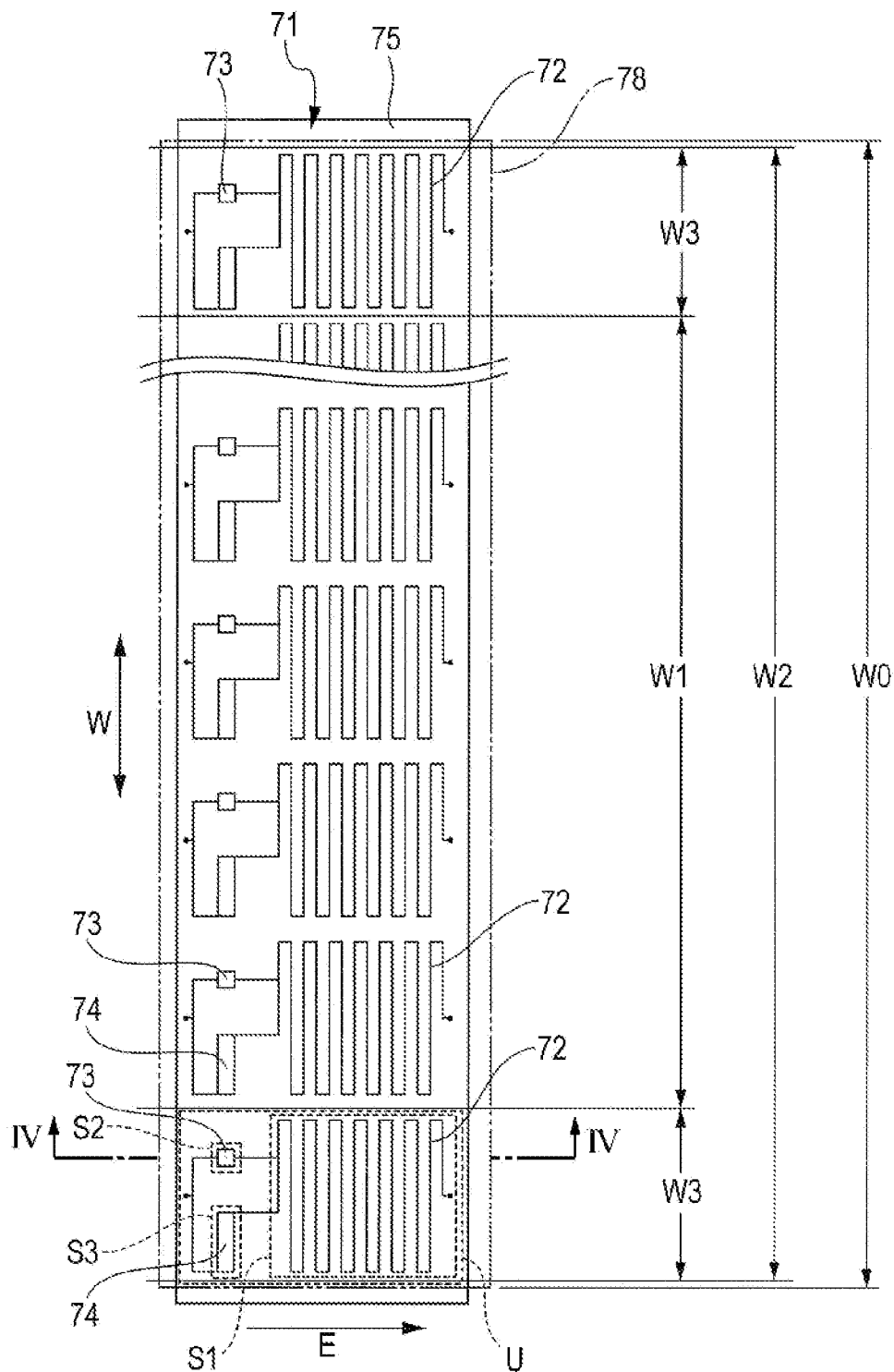


FIG. 4

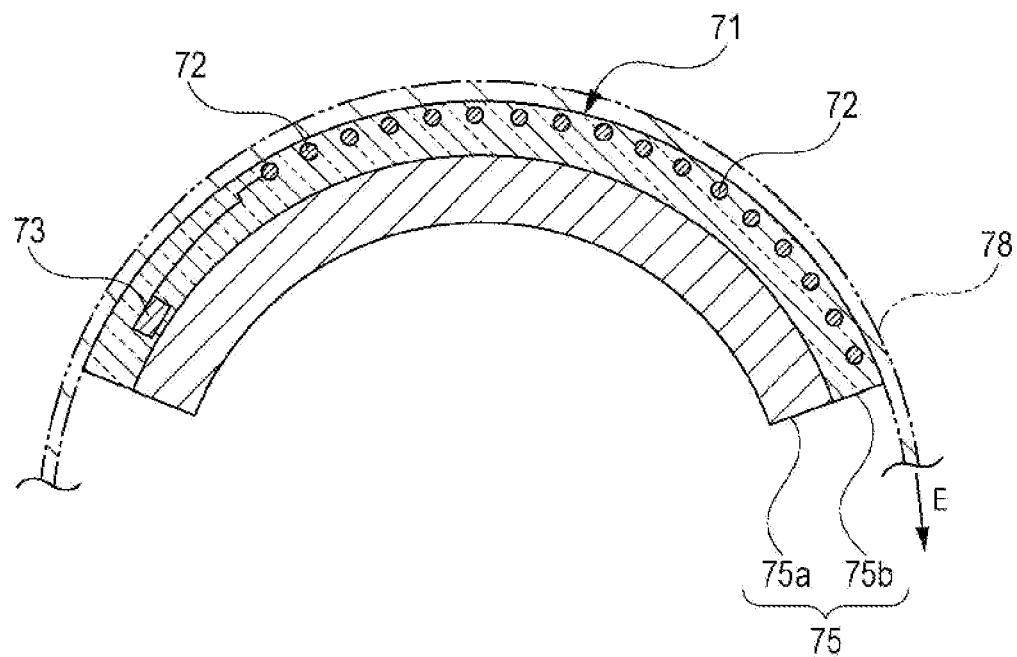


FIG. 5

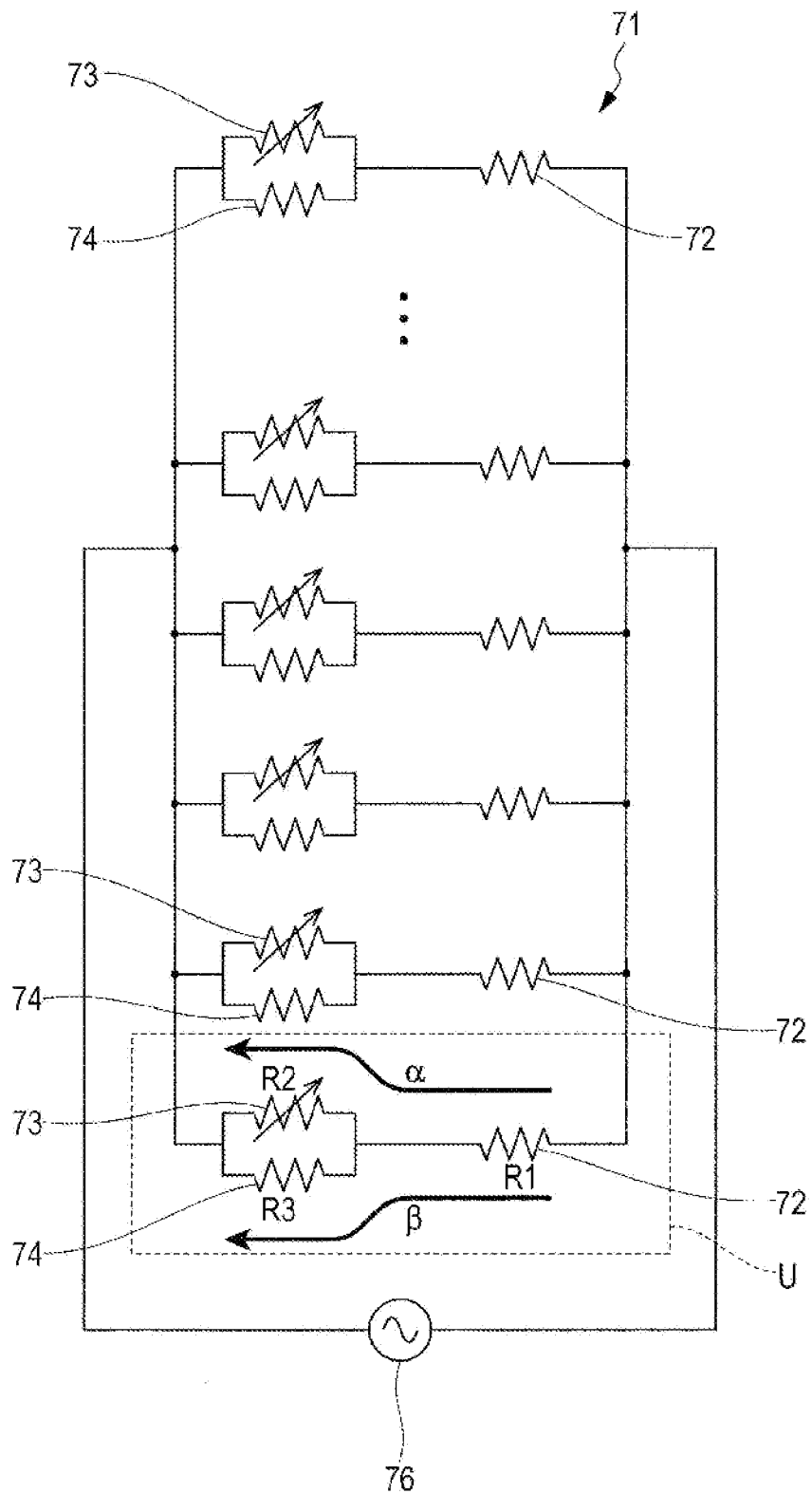


FIG. 6

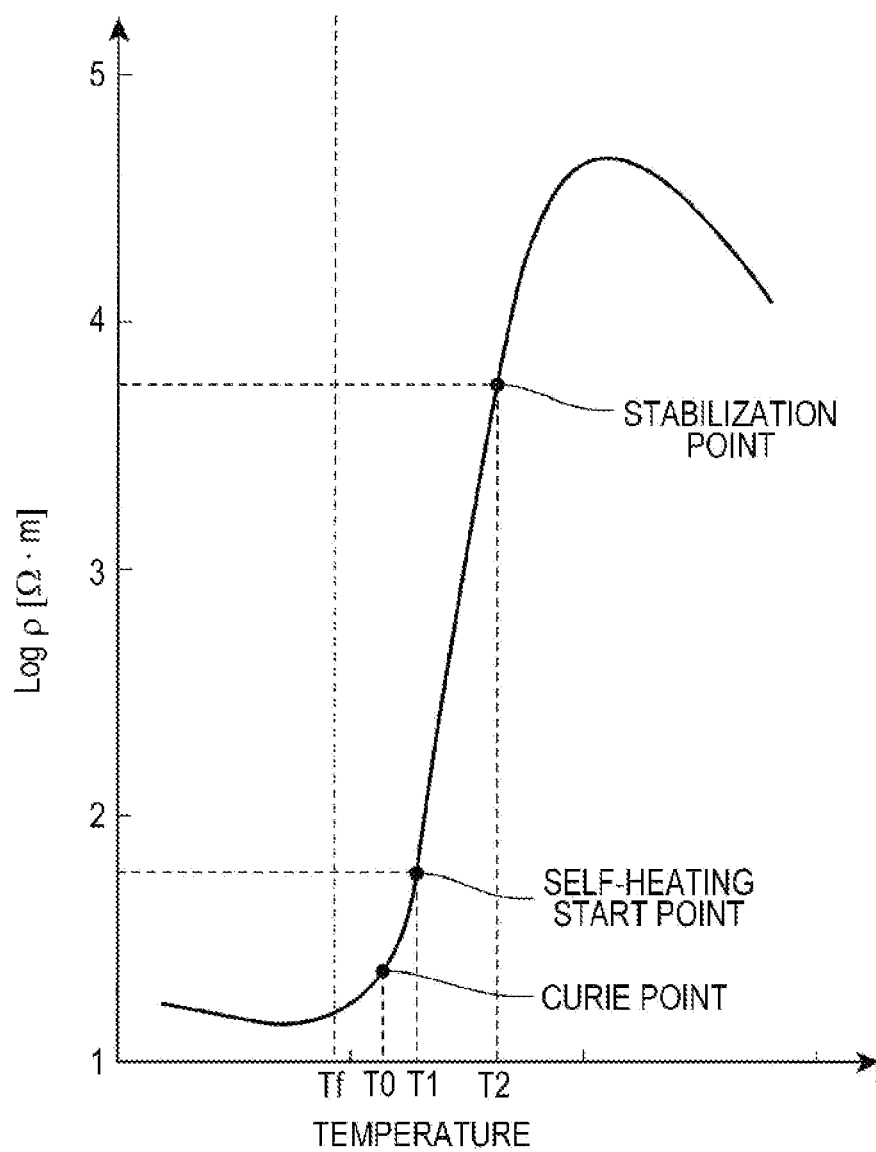


FIG. 7

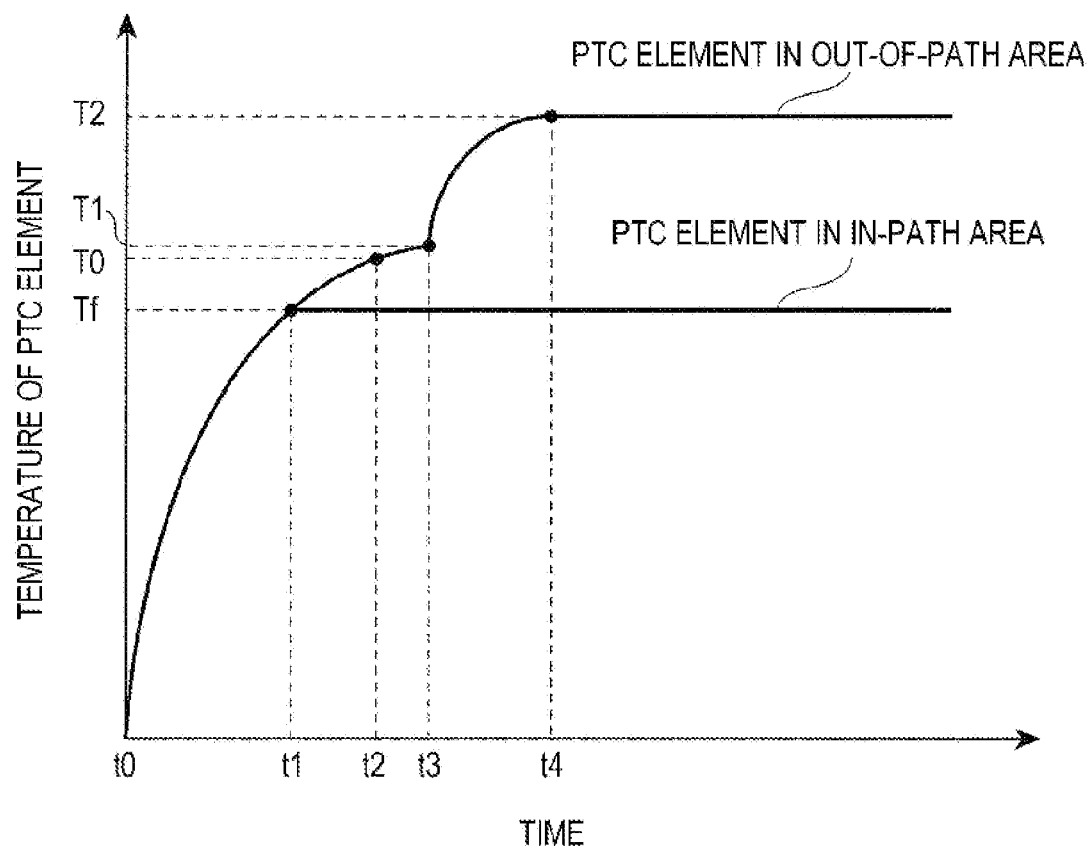


FIG. 8A

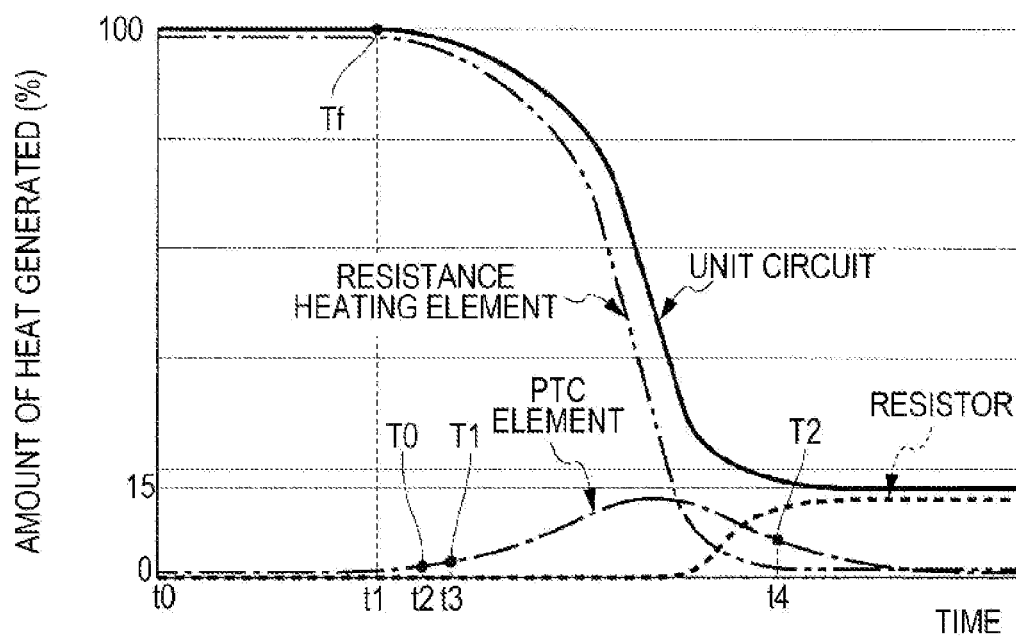


FIG. 8B

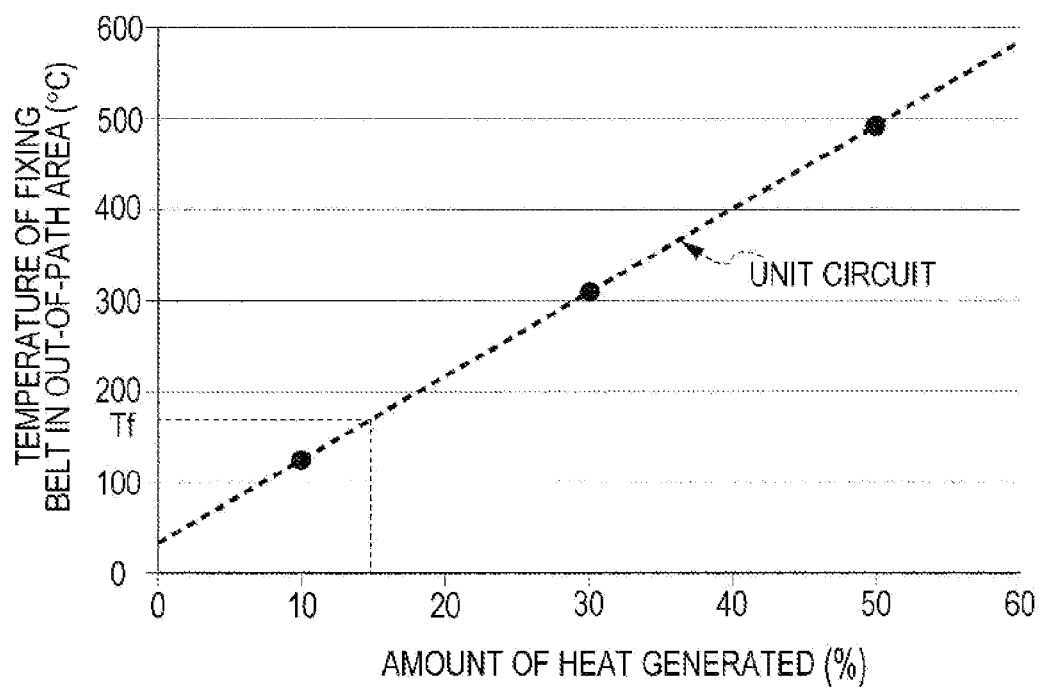


FIG. 9

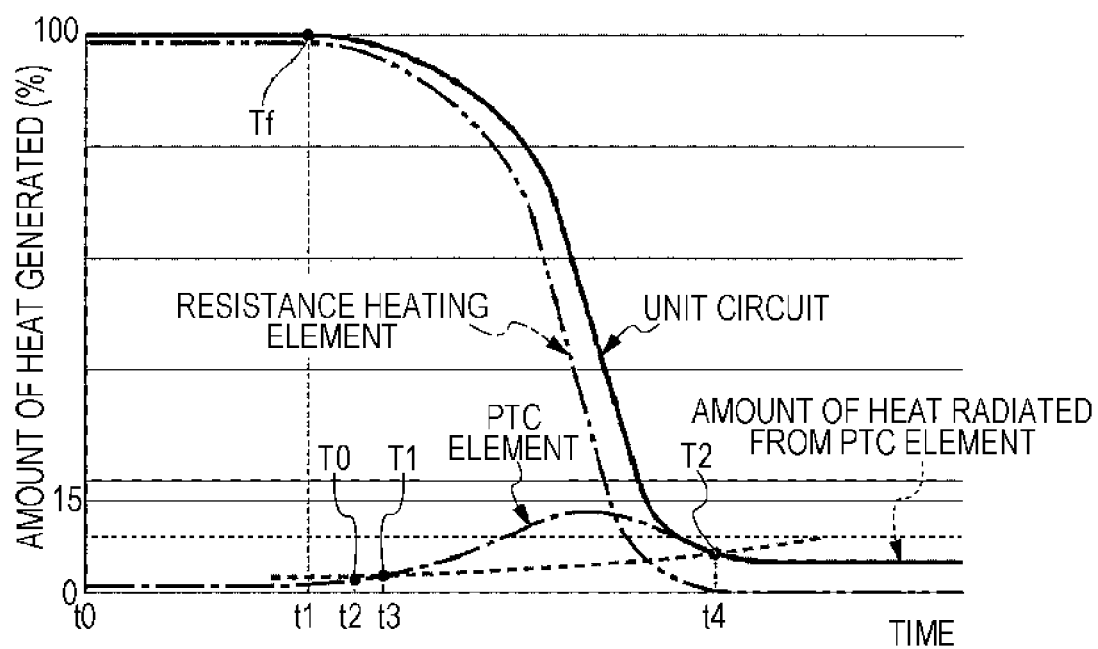


FIG. 10A

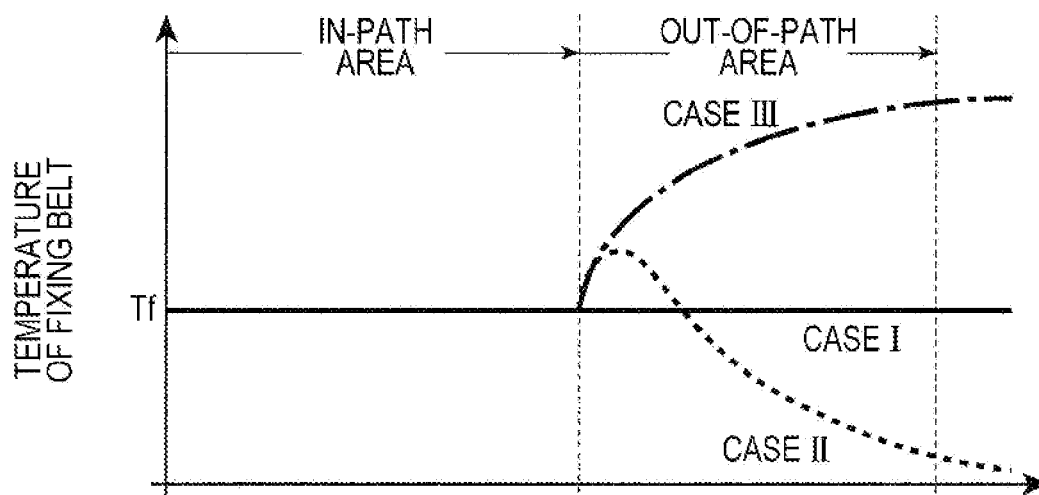


FIG. 10B

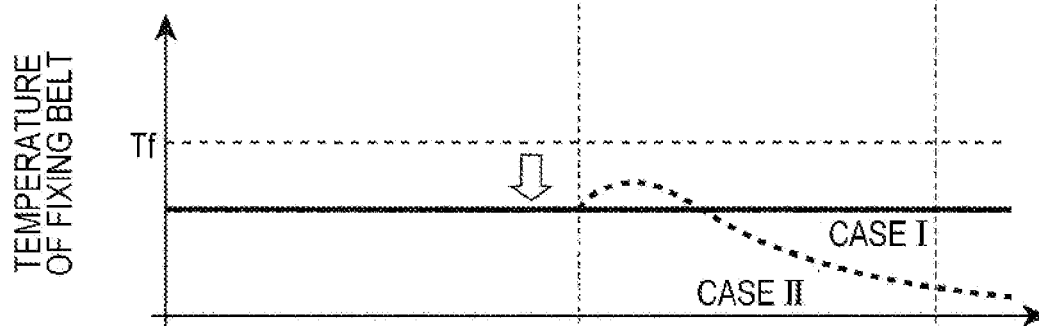


FIG. 10C

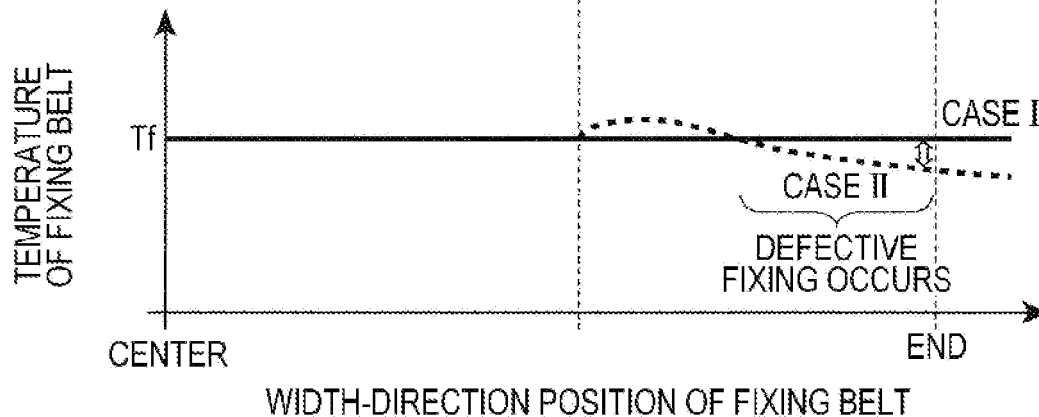
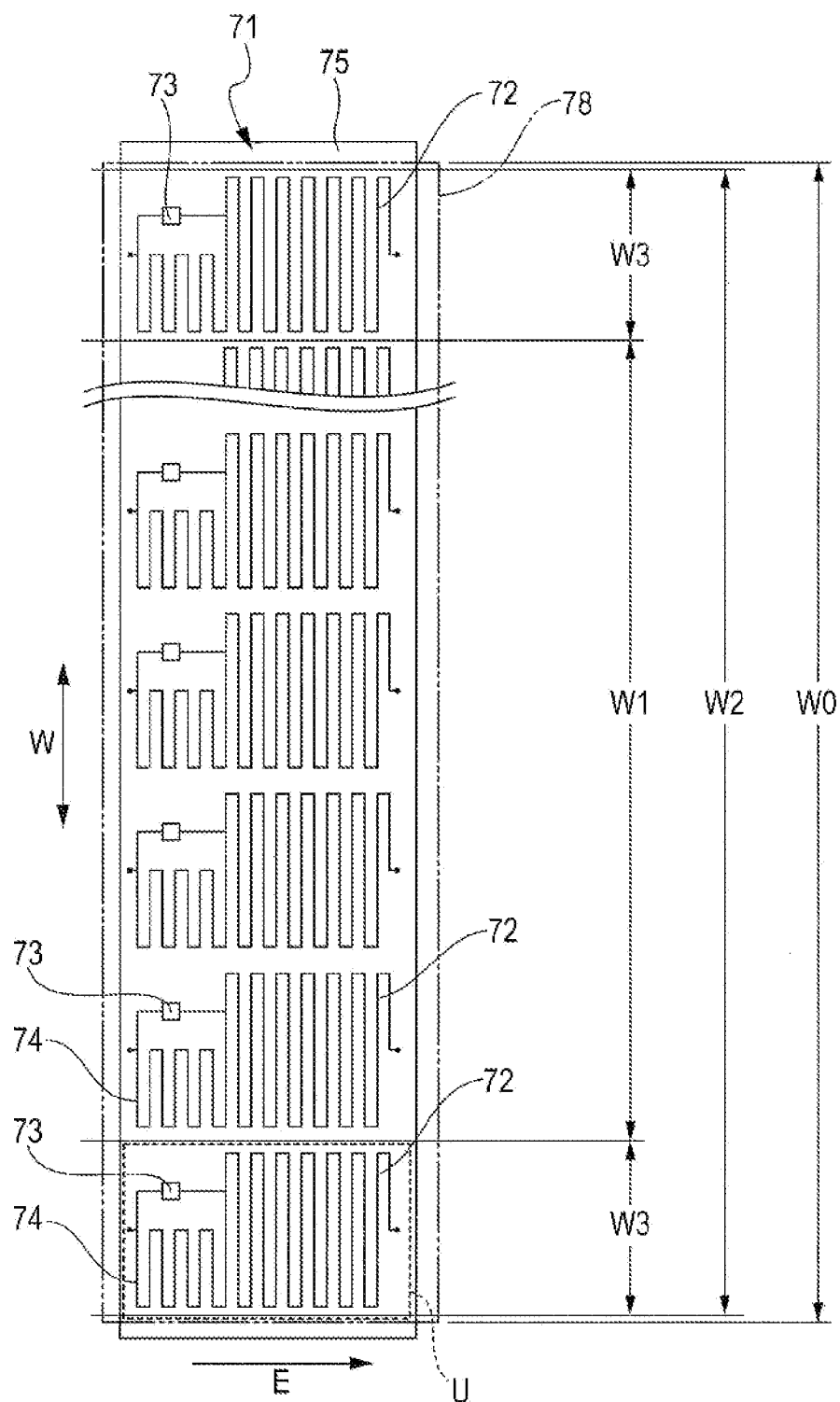


FIG. 11



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HEATING DEVICE, FIXING DEVICE, AND IMAGE FORMING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2015-032241 filed Feb. 20, 2015.

BACKGROUND

Technical Field

The present invention relates to a heating device, a fixing device, and an image forming apparatus.

SUMMARY

According to an aspect of the invention, there is provided a heating device including a rotating member that rotates, and plural unit circuits that are aligned in a width direction of the rotating member. The plural unit circuits each includes a heating body that heats the rotating member, a resistive element that is connected in series to the heating body and has a positive temperature coefficient, and a parallel circuit that is connected in parallel to the resistive element. The unit circuits are each configured such that, if a resistance value of the resistive element is increased with a rise of temperature of the resistive element, a current flows through the parallel circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention will be described in detail based on the following figures, wherein:

FIG. 1 is a schematic sectional view of an image forming apparatus according to a first exemplary embodiment of the present invention;

FIG. 2 is a sectional view of a fixing unit included in the image forming apparatus;

FIG. 3 illustrates a solid heater according to the first exemplary embodiment that is seen in a direction of arrow III illustrated in FIG. 2;

FIG. 4 is a sectional view of the solid heater that is taken along line IV-IV illustrated in FIG. 3;

FIG. 5 is an equivalent circuit diagram of the solid heater;

FIG. 6 is a graph illustrating the relationship between the temperature and the resistivity ρ ($\Omega\text{-cm}$) of a positive-temperature-coefficient (PTC) element;

FIG. 7 is a graph illustrating changes in the temperature of the PTC element with respect to time;

FIG. 8A is a graph illustrating changes in the amounts of heat (%) generated by a resistance heating body, the PTC element, a resistor, and a unit circuit, respectively, in an out-of-path area with respect to time;

FIG. 8B is a graph illustrating the relationship between the temperature ($^{\circ}\text{C.}$) of a fixing belt and the amount of heat (%) generated by the unit circuit in the out-of-path area;

FIG. 9 is a graph illustrating changes in the amounts of heat (%) generated by the resistance heating body, the PTC element, and the unit circuit, respectively, in the out-of-path area with respect to time in a case where the unit circuit does not include the resistor;

FIG. 10A is a graph illustrating the temperature distribution of the fixing belt in a width direction in a case where plural small-size sheets are sequentially subjected to a fixing process;

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FIG. 10B is a graph illustrating the temperature distribution of the fixing belt in the width direction in a case where the supply of a current from a power source has been stopped;

FIG. 10C is a graph illustrating the temperature distribution of the fixing belt in the width direction in a case where the supply of the current from the power source is restarted for the reheating of the fixing belt; and

FIG. 11 illustrates a solid heater according to a second exemplary embodiment of the present invention that is seen in a direction of arrow XI illustrated in FIG. 2.

DETAILED DESCRIPTION

First Exemplary Embodiment

Image Forming Apparatus 1

FIG. 1 is a schematic sectional view of an image forming apparatus 1 according to a first exemplary embodiment of the present invention. The image forming apparatus 1 is an electrophotographic color printer that prints images on the basis of image data.

The image forming apparatus 1 includes a body case 90, in which a sheet container unit 40 that contain sheets P (exemplary recording media), an image forming section 10 that forms an image on each of the sheets P, and a transporting portion 50 that transports the sheet P from the sheet container unit 40 through the image forming section 10 up to a sheet output port 96 provided in the body case 90. The image forming apparatus 1 further includes a controller 31 that controls the entire operation of the image forming apparatus 1, a communication unit 32 that communicates with, for example, a personal computer (PC) 3 or an image reading apparatus (scanner) 4 and receives image data therefrom, and an image processing unit 33 that processes the image data received by the communication unit 32.

The sheet container unit 40 includes a first sheet container 41 and a second sheet container 42 that contain sheets P of two different sizes, respectively. The first sheet container 41 contains sheets P1 of, for example, size A4. The second sheet container 42 contains sheets P2 of, for example, size B4. Hereinafter, the sheets P1 are also referred to as small-size sheets P1, and the sheets P2 are also referred to as large-size sheets P2. The two kinds of sheets P1 and P2 are collectively referred to as "sheets P" if there is no need to distinguish the sheets P1 and P2 from each other.

The transporting portion 50 includes a transport path 51 extending from each of the first sheet container 41 and the second sheet container 42, passing through the image forming section 10, and reaching the sheet output port 96, and pairs of transport rollers 52 that transport the sheet P along the transport path 51. The sheet P1 or P2 is transported by the transporting portion 50 such that the long sides thereof extend in the direction of transport represented by arrow C.

The image forming section 10 includes four image forming units 11Y, 11M, 11C, and 11K that are arranged at a predetermined interval. The image forming units 11Y, 11M, 11C, and 11K are hereinafter collectively referred to as "image forming units 11." The image forming unit 11 each include a photoconductor drum 12 on which an electrostatic latent image to be developed into a toner image is to be formed, a charging device 13 that charges the surface of the photoconductor drum 12 with a predetermined potential, a light-emitting-diode (LED) printhead 14 that exposes the photoconductor drum 12 charged by the charging device 13 to light emitted therefrom on the basis of a corresponding

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one of pieces of image data for different colors, a developing device **15** that develops the electrostatic latent image on the photoconductor drum **12** into a toner image, and a drum cleaner **16** that cleans the surface of the photoconductor drum **12** after the transfer.

The four image forming units **11Y**, **11M**, **11C**, and **11K** all have the same configuration, except toners contained in the respective developing devices **15**. The image forming unit **11Y** including the developing device **15** that contains a yellow (Y) toner forms a yellow toner image. Likewise, the image forming unit **11M** including the developing device **15** that contains a magenta (M) toner forms a magenta toner image, the image forming unit **11C** including the developing device **15** that contains a cyan (C) toner forms a cyan toner image, and the image forming unit **11K** including the developing device **15** that contains a black (K) toner forms a black toner image.

The image forming section **10** further includes an intermediate transfer belt **20** to which the toner images in the respective colors on the respective photoconductor drums **12** of the respective image forming units **11** are transferred in such a manner as to be superposed one on top of another, and first transfer rollers **21** that sequentially electrostatically transfer the toner images in the respective colors formed by the respective image forming units **11** to the intermediate transfer belt **20** (a first transfer). The image forming section **10** further includes a second transfer roller **22** provided in a second transfer part T and that electrostatically transfers the toner images in the respective colors superposed on the intermediate transfer belt **20** to a sheet P collectively (a second transfer), and a fixing unit **60** (an exemplary fixing device) that fixes the superposed toner images transferred to the sheet P to the sheet P.

The image forming apparatus **1** performs the following image forming process under the control of the controller **31**. Specifically, image data transmitted from the PC **3** or the scanner **4** is received by the communication unit **32** and is processed in a predetermined manner by the image processing unit **33**, whereby pieces of image data for the respective colors are generated. The pieces of image data for the respective colors are transmitted to the respective image forming units **11** provided for the respective colors. Subsequently, in the image forming unit **11K** that forms a black toner image, for example, the photoconductor drum **12** rotating in a direction of arrow A is charged with a predetermined potential by the charging device **13**.

Subsequently, the LED printhead **14** performs scan exposure on the photoconductor drum **12** on the basis of black image data transmitted from the image processing unit **33**, whereby an electrostatic latent image corresponding to the black image data is formed on the photoconductor drum **12**. The electrostatic latent image for black on the photoconductor drum **12** is then developed into a black toner image by the developing device **15**. Likewise, the image forming units **11Y**, **11M**, and **11C** form yellow, magenta, and cyan toner images, respectively.

The toner images in the respective colors thus formed on the photoconductor drums **12** of the image forming units **11** are sequentially electrostatically transferred to the intermediate transfer belt **20** by the respective first transfer rollers **21** in such a manner as to be superposed one on top of another while the intermediate transfer belt **20** is rotating in a direction of arrow B, whereby a set of superposed toner images in the respective colors is formed on the intermediate transfer belt **20**.

With the rotation of the intermediate transfer belt **20** in the direction of arrow B, the set of superposed toner images on

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the intermediate transfer belt **20** is transported to the second transfer part T. Synchronously with the transport of the set of superposed toner images to the second transfer part T, a sheet P is transported from the sheet container unit **40** in the direction of arrow C along the transport path **51** by the pairs of transport rollers **52** of the transporting portion **50**. Then, the set of superposed toner images on the intermediate transfer belt **20** is collectively electrostatically transferred, with a transfer electric field produced by the second transfer roller **22** in the second transfer part T, to the sheet P transported along the transport path **51**.

Subsequently, the sheet P carrying the set of superposed toner images that has been electrostatically transferred thereto is transported to the fixing unit **60** along the transport path **51**. The set of superposed toner images on the sheet P transported to the fixing unit **60** is subjected to heat and pressure applied thereto by the fixing unit **60**, whereby the set of superposed toner images is fixed to the sheet P. The sheet P having the fixed set of superposed toner images is transported along the transport path **51** and is discharged from the sheet output port **96** provided in the body case **90** onto a sheet stacking portion **95** that receives the sheet P.

Meanwhile, toners remaining on the photoconductor drums **12** after the first transfer and toners remaining on the intermediate transfer belt **20** after the second transfer are removed by the drum cleaners **16** and a belt cleaner **25**, respectively.

The above image forming process performed by the image forming apparatus **1** for printing an image on a sheet P is repeated a number of times corresponding to the number of pages to be printed.

Fixing Unit 60

FIG. 2 is a sectional view of the fixing unit **60** included in the image forming apparatus **1**.

The fixing unit **60** includes a heater unit **70** (an exemplary heating device) and a pressure roller **80** (an exemplary pressing member). The heater unit **70** and the pressure roller **80** each have a round columnar shape whose axis extends in the depth direction in FIG. 2.

The heater unit **70** includes a rotating fixing belt **78** (an exemplary rotating member), a solid heater **71** that has an arc sectional shape and generates heat, and a pressure pad **79** that is pressed by the pressure roller **80** with the fixing belt **78** interposed therebetween.

The fixing belt **78** has an endless cylindrical shape, and the inner circumferential surface thereof is in contact with the outer circumferential surface of the solid heater **71** and the pressure pad **79**. The fixing belt **78** is heated by being in contact with the solid heater **71**.

The pressure roller **80** is pressed against the outer circumferential surface of the fixing belt **78**, whereby a nip part N through which a sheet P carrying an unfixed set of superposed toner images passes is provided between the pressure roller **80** and the fixing belt **78**. The pressure roller **80** is rotated in a direction of arrow D by a driving device (not illustrated).

The sheet P transported to the nip part N by the transporting portion **50** (see FIG. 1) is heated by the fixing belt **78** and is pressed between the pressure pad **79** and the pressure roller **80** together with the fixing belt **78** in the nip part N. Thus, the unfixed set of superposed toner images carried by the sheet P is fixed to the sheet P.

In the nip part N, the sheet P that is in contact with the pressure roller **80** is moved in the direction of arrow C with the rotation of the pressure roller **80** in the direction of arrow D. The movement of the sheet P causes the fixing belt **78** that

is in contact with the sheet P to rotate in a direction of arrow E (a direction of forward rotation).

Solid Heater 71

FIG. 3 illustrates the solid heater 71 according to the first exemplary embodiment that is seen in a direction of arrow III illustrated in FIG. 2.

The solid heater 71 includes plural unit circuits U and a supporting member 75 that supports the plural unit circuits U. The unit circuits U each include a resistance heating body 72 (an exemplary heating body), a positive-temperature-coefficient (PTC) element 73 (an exemplary resistive element having a positive temperature coefficient), and a resistor 74.

The resistance heating body 72 is made of, for example, AgPd.

The PTC element 73 is made of, for example, barium titanate. The PTC element 73 is a small chip of size, for example, 2 mm (length)×2 mm (width)×0.1 mm (thickness).

The resistor 74 is, for example, a metal-glaze resistor.

The supporting member 75 extends in a width direction W of the fixing belt 78 (the direction in which the axis of rotation of the fixing belt 78 extends).

In each of the unit circuits U, the PTC element 73 is connected in series to the resistance heating body 72, and the resistor 74 is connected in parallel to the PTC element 73. That is, the resistor 74 serves as a parallel circuit with respect to the PTC element 73.

The PTC element 73 is provided on the upstream side of the fixing belt 78 in the direction of forward rotation E of the fixing belt 78. The resistance heating body 72 is provided on the downstream side of the fixing belt 78 in the direction of forward rotation E of the fixing belt 78. The resistor 74 is provided on the upstream side of the fixing belt 78 in the direction of forward rotation E of the fixing belt 78 and adjacent to the PTC element 73.

The unit circuits U are aligned in the width direction W of the fixing belt 78 on the supporting member 75 of the solid heater 71.

The size of each resistance heating body 72 in the width direction W is set such that adjacent ones of the resistance heating bodies 72 are positioned close to each other. Thus, the temperature distribution of the fixing belt 78 is made even.

As described above, the PTC element 73 is a small chip.

The resistor 74 is provided adjacent to the PTC element 73 such that the resistor 74 serves as a parallel circuit with respect to the PTC element 73.

Hence, in each of the unit circuits U provided on the supporting member 75, an area S2 occupied by the PTC element 73 and an area S3 occupied by the resistor 74 are each smaller than an area S1 occupied by the resistance heating body 72. Thus, the fixing belt 78 is efficiently heated by the resistance heating bodies 72.

Now, the relationship among a width W0 of the fixing belt 78 and respective widths W1 and W2 of the sheets P1 and P2 each carrying a set of superposed toner images that is to be fixed by the fixing unit 60 will be described.

The width W0 of the fixing belt 78 is slightly smaller than the length of the solid heater 71 in the width direction W of the fixing belt 78. Therefore, the fixing belt 78 is heated over the entirety of the width W0 by the plural resistance heating bodies 72 included in the solid heater 71.

The sheets P that are to be subjected to the fixing process in the nip part N of the fixing unit 60 include two kinds of sheets P1 and P2. The width W2 of the sheet P2 that is the larger one having the size, for example, B4 is only slightly

smaller than the width W0 of the fixing belt 78. Therefore, the sheet P2 is expected to cover all of the unit circuits U of the solid heater 71.

On the other hand, the width W1 of the sheet P1 that is the smaller one having the size, for example, A4 is much smaller than the width W0 of the fixing belt 78. Therefore, some of the unit circuits U that are provided at the two ends of the supporting member 75 are not expected to be covered with the sheet P1. In the case illustrated in FIG. 3, two unit circuits U provided at the two respective ends of the supporting member 75 are not expected to be covered with the sheet P1.

Hence, in an area extending in the width direction W and having the width W2 of the large-size sheet P2, portions (each having a width W3) on the outer sides of an area having the width W1 of the small-size sheet P1 are referred to as out-of-path areas that are out of the area over which the small-size sheet P1 passes during the fixing process performed on the small-size sheet P1, whereas a portion having the width W1 of the small-size sheet P1 is referred to as an in-path area over which the sheet P1 passes during the fixing process performed on the small-size sheet P1.

In the first exemplary embodiment, the unit circuits U each including the resistance heating body 72, the PTC element 73, and the resistor 74 are arranged over the entirety of an in-path area for the large-size sheet P2 that has the width W2. Alternatively, only the resistance heating bodies 72 may be provided in the in-path area for the small-size sheet P1 that has the width W1, and the unit circuits U each including the resistance heating body 72, the PTC element 73, and the resistor 74 may be provided only in the out-of-path areas for the small-size sheet P1 that each have the width W3.

FIG. 4 is a sectional view of the solid heater 71 that is taken along line IV-IV illustrated in FIG. 3.

The section of the supporting member 75 has an arc shape. The supporting member 75 includes a base member 75a provided on the radially inner side thereof, and a glass coat 75b stacked on the base member 75a on the radially outer side thereof.

The base member 75a is made of, for example, stainless steel, or a cladding material in which a stainless-steel plate and a copper plate are joined to each other in the thickness direction thereof.

The resistance heating bodies 72, the PTC elements 73, and the resistors 74 are provided in the glass coat 75b stacked on the base member 75a. The glass coat 75b insulates the resistance heating bodies 72, the PTC elements 73, and the resistors 74 from the fixing belt 78. The glass coat 75b may be replaced with a member made of another insulating material such as resin.

The fixing belt 78 is stretched over the outer circumferential surface of the glass coat 75b and rotates in the direction of arrow E while being in contact with the glass coat 75b.

The solid heater 71 is manufactured as follows, for example.

First, a glass layer that serves as an insulating layer is formed on the base member 75a by screen printing and is baked. Subsequently, resistance heating bodies 72 are formed on the glass layer by screen printing. Furthermore, wiring lines for connecting the resistance heating bodies 72 to PTC elements 73 and resistors 74 to be formed thereafter are formed on the glass layer by screen printing. Then, the PTC elements 73 and the resistors 74 are provided at predetermined positions, respectively. Subsequently, a glass layer serving as an insulating layer is formed over the wiring

lines, the resistance heating bodies **72**, the PTC elements **73**, and the resistors **74** and is baked. The baking causes the glass layer to undergo viscous flow, whereby the outer circumferential surface of the glass coat **75b** is smoothed.

Thus, the glass coat **75b** in which the wiring lines, the resistance heating bodies **72**, the PTC elements **73**, and the resistors **74** are provided is obtained.

The solid heater **71** may be manufactured in any other way.

FIG. **5** is an equivalent circuit diagram of the solid heater **71**.

In each of the unit circuits **U**, the PTC element **73** is connected in series to the resistance heating body **72**, and the resistor **74** is connected in parallel to the PTC element **73**.

The resistance heating body **72** has a resistance value **R1**. The PTC element **73** has a resistance value **R2**. The resistor **74** has a resistance value **R3**.

The plural unit circuits **U** are connected in parallel to a power source **76**.

The power source **76** has, for example, an alternating-current (AC) output of 100 V.

PTC Element **73**

FIG. **6** is a graph illustrating the relationship between the temperature and the resistivity ρ ($\Omega\cdot\text{cm}$) of the PTC element **73**.

When the temperature of the PTC element **73** exceeds a Curie temperature **T0** (denoted as Curie point in the graph), the resistivity of the PTC element **73** increases more rapidly than the resistivity of a typical resistor made of metal or the like. That is, the PTC element **73** has a positive temperature coefficient.

When the temperature of the PTC element **73** exceeds a temperature **T1**, the PTC element **73** starts to generate heat by itself (self-heating) and the temperature of the PTC element **73** rises (this temperature is denoted as self-heating start point in the graph). Accordingly, the resistance value **R2** of the PTC element **73** further increases.

The amount of heat generated by the PTC element **73** becomes the same as the amount of heat radiated from the PTC element **73** at a temperature **T2**, where the temperature and the resistance value of the PTC element **73** are stabilized (this temperature is denoted as stabilization point in the graph).

The Curie temperature **T0** of the PTC element **73** is set to a value above a target temperature (a fixing temperature **Tf**) that needs to be reached for fixing the set of superposed toner images to the sheet **P**.

As described above, the PTC element **73** has a positive temperature coefficient, and the resistance value **R2** thereof changes with the temperature thereof. Hence, in FIG. **5**, the PTC element **73** is represented by a symbol of a variable resistor.

The resistance value **R2** of the PTC element **73** that is below the Curie temperature **T0** is set to about $\frac{1}{100}$ of the resistance value **R1** of the resistance heating body **72**. For example, if the resistance value **R1** of the resistance heating body **72** is 100 Ω , the resistance value **R2** of the PTC element **73** at a normal ambient temperature is 1 Ω .

On the other hand, the resistance value **R2** of the PTC element **73** that is at the temperature **T2** is set to about 100 times the resistance value **R1** of the resistance heating body **72**. For example, if the resistance value **R1** of the resistance heating body **72** is 100 Ω , the resistance value **R2** of the PTC element **73** at the stabilization point (the temperature **T2**) is 10⁴ Ω .

The resistance value **R3** of the resistor **74** is set to several times the resistance value **R1** of the resistance heating body

72. For example, if the resistance value **R1** of the resistance heating body **72** is 100 Ω , the resistance value **R3** of the resistor **74** is 600 Ω .

That is, the resistance value **R3** of the resistor **74** is larger than the resistance value **R2** of the PTC element **73** at a temperature below the Curie temperature **T0** and is smaller than the resistance value **R2** of the PTC element **73** at the temperature **T2**.

When the PTC element **73** is at a temperature below the Curie temperature **T0**, the resistance value **R2** of the PTC element **73** is smaller than the resistance value **R3** of the resistor **74**. Hence, in each of the unit circuits **U** illustrated in FIG. **5**, the current takes a route α that passes through the resistance heating body **72** and the PTC element **73**.

On the other hand, when the PTC element **73** is at the temperature **T2**, the resistance value **R2** of the PTC element **73** is larger than the resistance value **R3** of the resistor **74**. Hence, in each of the unit circuits **U** illustrated in FIG. **5**, the current takes a route β that passes through the resistance heating body **72** and the resistor **74**.

That is, the route of the current is changed to the route β passing through the resistance heating body **72** and the resistor **74** in accordance with the temperature of the PTC element **73**, whereby the amount of current is controlled. In other words, the amount of heat generated by the unit circuit **U** (the resistance heating body **72** and the PTC element **73** or the resistor **74**) is controlled.

FIG. **7** is a graph illustrating changes in the temperature of the PTC element **73** with respect to time. In the graph illustrated in FIG. **7**, the vertical axis represents the temperature of the PTC element **73**, and the horizontal axis represents time. The time represented by the horizontal axis is only explanatory and may be different from the actual time of temperature change.

Suppose that a small-size sheet **P1** is transported through the fixing unit **60**. In this case, the temperature of the PTC element **73** is different between that in the in-path area (the area having the width **W1** in FIG. **3**) over which the small-size sheet **P1** passes and that in each of the out-of-path areas (the areas having the width **W3** in FIG. **3**) that are on the outer sides of the area over which the small-size sheet **P1** passes. Such a phenomenon occurs as follows.

When a current is supplied to the solid heater **71** from the power source **76** (see FIG. **5**) at time **t0**, the fixing belt **78** starts to be heated. At time **t0**, the PTC element **73** is below the Curie temperature **T0**. Therefore, in each of the unit circuits **U**, the current takes the route α , illustrated in FIG. **5**, passing through the resistance heating body **72** and the PTC element **73**.

In this state, the resistance value **R1** of the resistance heating body **72** is about 100 times larger than the resistance value **R2** of the PTC element **73**. Hence, the PTC element **73** consumes substantially no electricity, compared with the resistance heating body **72**, and generates substantially no heat. That is, the fixing belt **78** is heated with the heat generated by the resistance heating body **72**.

The fixing belt **78** that is rotating in the direction of arrow **E** illustrated in FIG. **3** is heated over the entirety, in the width direction **W**, of a portion thereof extending over the solid heater **71** by the resistance heating bodies **72** through the glass coat **75b** (see FIG. **4**).

When the temperature of the fixing belt **78** rises, the temperature of each PTC element **73** also rises. At time **t1** when the temperature of the fixing belt **78** (the PTC element **73**) has reached the fixing temperature **Tf**, the small-size sheet **P1** starts to be transported through the fixing unit **60**.

Here, the PTC elements **73** provided in the in-path area over which the small-size sheet **P1** passes will first be described.

When the fixing belt **78** that has been heated as described above rotates and the heated portion thereof has reached the nip part **N** (see FIG. 2), the heated portion of the fixing belt **78** comes into contact with the sheet **P1**. In this step, an unfixed set of superposed toner images on the sheet **P1** is heated by the fixing belt **78** and is pressed between the pressure pad **79** and the pressure roller **80** in the nip part **N**. Thus, the unfixed set of superposed toner images on the sheet **P1** is fixed to the sheet **P1**.

Consequently, the temperature of the portion of the fixing belt **78** that has been in contact with the sheet **P1** drops. When the fixing belt **78** further rotates in the direction of arrow **E** and the portion whose temperature has dropped returns to the solid heater **71** illustrated in FIG. 2, the portion is reheated to the fixing temperature T_f by the resistance heating bodies **72** through the glass coat **75b**.

In this step, the glass coat **75b** is cooled by exchanging heat with the temperature-dropped portion of the fixing belt **78**. Therefore, the temperatures of the PTC elements **73** in the glass coat **75b** do not exceed the Curie temperature T_0 (see FIG. 6).

Thus, the PTC elements **73** provided in the in-path area over which the sheet **P1** passes are kept at the fixing temperature T_f .

Now, the PTC elements **73** provided in the out-of-path areas that are on the outer sides of the area over which the small-size sheet **P1** passes will be described.

The out-of-path areas of the solid heater **71** do not come into contact with the sheet **P1**. Therefore, in the out-of-path areas, the fixing belt **78** continues to be heated by the resistance heating bodies **72**. Accordingly, the temperature of each of the PTC elements **73** in the out-of-path areas continue to rise.

In such a case, the temperature of each PTC element **73** reaches the Curie temperature T_0 at time t_2 , and the PTC element **73** is further heated.

Then, at time t_3 , the temperature of the PTC element **73** reaches the temperature T_1 , where the PTC element **73** starts self-heating and is further heated.

Eventually, at time t_4 , the temperature of the PTC element **73** reaches the temperature T_2 , i.e., the stabilization point, and is maintained at the temperature T_2 .

Amount of Heat Generated

The amounts of heat generated by the resistance heating body **72**, the PTC element **73**, and the resistor **74** in each of the out-of-path areas that are on the outer sides of the area over which the small-size sheet **P1** passes will now be described.

FIG. 8A is a graph illustrating changes in the amounts of heat (%) generated by the resistance heating body **72**, the PTC element **73**, the resistor **74**, and the unit circuit **U**, respectively, in the out-of-path area with respect to time. FIG. 8B is a graph illustrating the relationship between the temperature ($^{\circ}\text{C.}$) of the fixing belt **78** and the amount of heat (%) generated by the unit circuit **U** in the out-of-path area. In FIG. 8A, the vertical axis represents the amount of heat generated (%), and the horizontal axis represents time. The amount of heat generated by the unit circuit **U** is the sum of the respective amounts of heat generated by the resistance heating body **72**, the PTC element **73**, and the resistor **74**. In FIG. 8B, the vertical axis represents the temperature ($^{\circ}\text{C.}$) of the fixing belt **78** in the out-of-path area, and the horizontal axis represents the amount of heat generated (%) by the unit circuit **U**.

The amount of heat (%) generated by the unit circuit **U** is calculated by defining the amount of heat generated in the case where the PTC element **73** is below the Curie temperature T_0 as 100%.

Referring to FIG. 8A, changes in the amounts of heat generated by the resistance heating body **72**, the PTC element **73**, the resistor **74**, and the unit circuit **U** in the out-of-path area with respect to time will now be described.

Suppose that a current starts to be supplied to the solid heater **71** at time t_0 . At time t_0 , the PTC element **73** is below the Curie temperature T_0 . Therefore, the current takes the route α (see FIG. 5) passing through the resistance heating body **72** and the PTC element **73** as described above.

Hence, the total amount of heat generated is the sum of the respective amounts of heat generated by the resistance heating body **72** and the PTC element **73**. Note that most of the total amount of heat is generated by the resistance heating body **72**.

At time t_1 , the temperature of the fixing belt **78** reaches the fixing temperature T_f , and a small-size sheet **P1** starts to be transported through the fixing unit **60**. The sheet **P1** does not come into contact with the fixing belt **78** in the out-of-path areas. Therefore, the heat of the fixing belt **78** is not radiated, and the temperature of the PTC element **73** continues to rise.

At time t_2 , the temperature of the PTC element **73** reaches the Curie temperature T_0 . Accordingly, the resistance value R_2 of the PTC element **73** starts to increase.

At time t_3 , the temperature of the PTC element **73** reaches the temperature T_1 . Then, the voltage applied to the PTC element **73** increases, and the amount of heat generated increases. When the amount of heat generated by the PTC element **73** becomes larger than the amount of heat radiated to the base member **75a** of the solid heater **71** and to the fixing belt **78**, the temperature of the PTC element **73** rapidly rises, that is, the PTC element **73** starts self-heating. When the resistance value R_2 of the PTC element **73** rapidly increases with the self-heating of the PTC element **73**, the current starts to be reduced. Accordingly, the amount of heat generated by the PTC element **73** starts to be reduced. If the resistance value R_2 of the PTC element **73** exceeds the resistance value R_3 of the resistor **74**, the current taking the route α also takes the route β passing through the resistance heating body **72** and the resistor **74** (see FIG. 5).

Then, at time t_4 , the amount of heat generated by the PTC element **73** and the amount of heat radiated from the PTC element **73** becomes the same again, and the temperature of the PTC element **73** is stabilized at the temperature T_2 .

After time t_4 , the resistance value R_2 of the PTC element **73** is large, and the current is small. Therefore, the amount of heat generated by the PTC element **73** does not contribute to the amount of heat generated by the unit circuit **U**. That is, the amount of heat generated by the unit circuit **U** is the sum of the amount of heat generated by the resistance heating body **72** and the amount of heat generated by the resistor **74**. If the resistance value R_3 of the resistor **74** is larger than the resistance value R_1 of the resistance heating body **72**, most of the heat is generated by the resistor **74**, as described above.

Supposing that, for example, the resistance value R_1 of the resistance heating body **72** is 100Ω and the resistance value R_3 of the resistor **74** is 600Ω , the amount of heat generated in the case where the current takes the route β (see FIG. 5) is 15% of the amount of heat generated in the case where the current takes the route α (see FIG. 5).

The above state is maintained unless the supply of power from the power source **76** is stopped and the temperature of the PTC element **73** is reduced to a value below the Curie temperature **T0**.

Referring now to FIG. **8B**, the relationship between the temperature of the fixing belt **78** and the amount of heat (%) generated by the unit circuit **U** in the out-of-path area will be described.

The amount of heat generated by the unit circuit **U** is set with consideration for the temperature of the fixing belt **78** in the out-of-path area. In the exemplary case described above, if the amount of heat generated by the unit circuit **U** is set to 15%, the temperature of the fixing belt **78** in the out-of-path area is maintained at the fixing temperature **Tf** of 170° C.

The amount of heat generated (%) is set on the basis of the resistance value **R1** of the resistance heating body **72** and the resistance value **R3** of the resistor **74**.

Here, a comparative case where the unit circuits **U** of the solid heater **71** each do not include the resistor **74** will be described.

FIG. **9** is a graph illustrating changes in the amounts of heat (%) generated by the resistance heating body **72**, the PTC element **73**, and the unit circuit **U**, respectively, in the out-of-path area with respect to time in a case where the unit circuit **U** does not include the resistor **74**. In the graph illustrated in FIG. **9**, the vertical axis represents the amount of heat generated (%), and the horizontal axis represents time. The amount of heat generated by the unit circuit **U** is the sum of the amount of heat generated by the resistance heating body **72** and the amount of heat generated by the PTC element **73**.

In the case where the unit circuit **U** does not include the resistor **74**, the current take the route α passing through the resistance heating body **72** and the PTC element **73**, as is seen from FIG. **3**.

The changes in the amount of heat generated (%) that are observed from time **t0** to time **t4** are the same as those illustrated in FIG. **8A**, and description thereof is omitted.

The amount of heat generated by the unit circuit **U** at time **0** is 100%. At time **0**, most of the heat is generated by the resistance heating body **72**.

As graphed in FIG. **9**, in the case where the unit circuit **U** does not include the resistor **74**, most of the heat in the out-of-path area of the solid heater **71** after time **t4** is generated by the PTC element **73**. However, since the resistance value **R2** of the PTC element **73** is large and the current flowing therethrough is small, it is difficult to heat the fixing belt **78** with the heat generated by the PTC element **73**.

That is, providing the resistor **74** in the unit circuit **U** allows the current to take the route β (see FIG. **5**) passing through the resistance heating body **72** and the resistor **74** if the temperature of the PTC element **73** has reached the temperature **T2** and the resistance value **R2** of the PTC element **73** has increased. Thus, the temperature of the fixing belt **78** in the out-of-path area is prevented from dropping. Temperature Distribution of Fixing Belt **78**

FIGS. **10A** to **10C** are graphs illustrating the temperature distribution of the fixing belt **78** in the width direction **W**. FIG. **10A** illustrates a case where plural small-size sheets **P1** are sequentially subjected to the fixing process. FIG. **10B** illustrates a case where the supply of the current from the power source **76** has been stopped. FIG. **10C** illustrates a case where the supply of the current from the power source **76** is restarted for the reheating of the fixing belt **78**. The horizontal axis of each of the graphs illustrated in FIGS. **10A**

to **10C** represents the position of the fixing belt **78** in the width direction **W**, from the center to an end of the fixing belt **78** (having the width **W0**) illustrated in FIG. **3**. As illustrated in FIG. **3**, a central portion corresponds to the in-path area for the small-size sheet **P1**, and an end portion corresponds to the out-of-path area for the small-size sheet **P1**.

In Case I, the unit circuit **U** includes the resistance heating body **72**, the PTC element **73**, and the resistor **74**. In Case II, the unit circuit **U** includes the resistance heating body **72** and the PTC element **73** but does not include the resistor **74**. In Case III, the unit circuit **U** includes the resistance heating body **72** but does not include the PTC element **73** and the resistor **74**.

Referring to FIG. **10A**, when plural small-size sheets **P1** are sequentially subjected to the fixing process, a portion of the fixing belt **78** in the in-path area for the small-size sheet **P1** radiates heat by coming into contact with each of the sheets **P1** and is maintained at the fixing temperature **Tf** in each of Cases I, II, and III.

However, a portion of the fixing belt **78** in the out-of-path area for the sheet **P1** does not come into contact with the sheet **P1** and does not therefore radiate heat to the sheet **P1**.

In Case III where the unit circuit **U** includes the resistance heating body **72** but does not include the PTC element **73** and the resistor **74**, the current continues to be supplied to the resistance heating body **72**. Therefore, the temperature of the fixing belt **78** in the out-of-path area continues to rise. In the out-of-path area, as represented by the dash-dot line in FIG. **10A**, the temperature of the fixing belt **78** becomes higher from the boundary between the in-path area and the out-of-path area toward the end. Hence, the end portion of the fixing belt **78** may be overheated.

Now, Case II where the unit circuit **U** includes the resistance heating body **72** and the PTC element **73** but does not include the resistor **74** will be discussed. In the stabilized state observed after time **t4** where the temperature of the PTC element **73** is above the Curie temperature **T0** and the resistance value **R2** has increased correspondingly, the amount of heat generated by the unit circuit **U** is, as graphed in FIG. **9**, below 15%, which is too low to maintain the temperature in the out-of-path area to be substantially the same as the temperature in the in-path area. That is, as graphed by the dotted line in FIG. **10A**, the temperature of the fixing belt **78** in the out-of-path area becomes lower from the boundary between the in-path area and the out-of-path area toward the end.

In Case II, the temperature of the fixing belt **78** rises in a portion of the out-of-path area that is near the boundary between the in-path area and the out-of-path area. Such a phenomenon occurs in a case where the boundary between the in-path area and the out-of-path area extends over the unit circuit **U** including the resistance heating body **72** and the PTC element **73**. For example, if a part of the PTC element **73** overlaps the in-path area, the temperature of the PTC element **73** does not exceeds the Curie temperature **T0**. Hence, the current flows through the resistance heating body **72**, and the temperature of the fixing belt **78** in a portion of the out-of-path area that is near the boundary between the in-path area and the out-of-path area rises.

Such a phenomenon may occur also in Cases I and III but is not graphed.

In Case I where the unit circuit **U** includes the resistance heating body **72**, the PTC element **73**, and the resistor **74**, when the temperature of the PTC element **73** exceeds the Curie temperature **T0** and the resistance value **R2** increases in the out-of-path area, the current takes the route β (see FIG. **5**) passing through the resistance heating body **72** and

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the resistor **74**. Therefore, the temperature of the fixing belt **78** in the out-of-path area is maintained at a predetermined temperature (hereinafter, the predetermined temperature is regarded as the fixing temperature T_f). That is, in Case I, the difference between the temperature in the in-path area and the temperature in the out-of-path area is suppressed to a smaller value than in Case II.

Referring now to FIG. **10B**, to cancel the situation where the resistance value R_2 of the PTC element **73** has increased, the supply of the current from the power source **76** is stopped. Hereinafter, description of Case III is omitted.

Accordingly, the temperature distribution of the fixing belt **78** has a similar tendency, both in the in-path area and in the out-of-path area, to the temperature distribution observed before the supply of the current from the power source **76** is stopped (the temperature distribution illustrated in FIG. **10A**).

That is, Case II exhibits a tendency that the temperature of the fixing belt **78** in the out-of-path area becomes lower from the boundary between the in-path area and the out-of-path area toward the end.

In contrast, in Case I where the temperature difference between the in-path area and the out-of-path area is suppressed to a small value, the temperature of the fixing belt **78** is low and is evenly distributed both in the in-path area and in the out-of-path area.

Note that the PTC element **73** has a small heat capacity. Therefore, when the supply of the current from the power source **76** is stopped, the temperature of the PTC element **73** drops to a temperature below the Curie temperature T_0 rapidly, for example, in one second or shorter.

In the case graphed in FIG. **10C** where the supply of the current from the power source **76** is restarted, the fixing belt **78** is reheated by the solid heater **71**. In this case, the temperature distribution of the fixing belt **78** has a similar tendency to the temperature distribution observed before the fixing belt **78** is reheated.

Case II exhibits a tendency that the temperature of the fixing belt **78** becomes lower from the boundary between the in-path area and the out-of-path area toward the end. Particularly, the temperature of the fixing belt **78** is low in a portion near the end. Therefore, the temperature of the fixing belt **78** in the portion near the end (the end portion) does not easily reach the fixing temperature T_f .

Hence, if a large-size sheet **P2** is fed into the fixing unit **60** in a state where the temperature of the fixing belt **78** in the in-path area has reached the fixing temperature T_f but the end portions of the fixing belt **78** are still below the fixing temperature T_f , defective fixing may occur in the end portions of the fixing belt **78** that are below the fixing temperature T_f .

To avoid such a situation, the fixing process may be withheld until the temperature in each of the end portions of the fixing belt **78** reaches the fixing temperature T_f . In such a case, however, the waiting time (standby time) increases.

In contrast, in Case I where the temperature difference between the in-path area and the out-of-path area is small before the fixing belt **78** is reheated, the temperature difference between the in-path area and the out-of-path area that is observed after the fixing belt **78** is reheated is also small. Hence, the difference in time taken before the temperature of the fixing belt **78** reaches the fixing temperature T_f is small between that in the in-path area and that in the out-of-path area. That is, the waiting time (standby time) taken before the temperature of the fixing belt **78** reaches the fixing temperature T_f is shorter and the probability that defective

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fixing may occur is lower than in the case where the unit circuit **U** does not include the resistor **74**.

Even if Case I exhibits the tendency observed in Case II graphed in FIG. **10A** that the temperature rises in a portion of the out-of-path area that is near the boundary between the in-path area and the out-of-path area, defective fixing does not occur because the temperature of the fixing belt **78** in the above portion is higher than the fixing temperature T_f .

The width of the portion where the temperature becomes high may be reduced by reducing the pitch of the unit circuits **U** that are aligned in the solid heater **71** in the width direction **W** of the fixing belt **78**.

Second Exemplary Embodiment

In the first exemplary embodiment, the resistor **74** included in each of the unit circuits **U** of the solid heater **71** is, for example, a chip resistor such as a metal-glaze resistor.

In a second exemplary embodiment of the present invention, the resistor **74** is made of the same resistive material as the resistance heating body **72**. The second exemplary embodiment differs from the first exemplary embodiment in the configuration of the solid heater **71**, and the other elements employed in the second exemplary embodiments are the same as those employed in the first exemplary embodiment. The following description focuses on the difference from the first exemplary embodiment, and description of the elements that are the same as those of the first exemplary embodiment is omitted.

Solid Heater **71**

FIG. **11** illustrates a solid heater **71** according to the second exemplary embodiment that is seen in a direction of arrow **XI** illustrated in FIG. **2**.

The solid heater **71** includes plural unit circuits **U** and a supporting member **75** that supports the plural unit circuits **U**. The unit circuits **U** each include a resistance heating body **72**, a PTC element **73**, and a resistor **74**.

The resistor **74** according to the second exemplary embodiment is provided as an extension of the resistance heating body **72**. That is, the resistor **74** is made of, for example, AgPd. The resistor **74** may be made of a material different from the material of the resistance heating body **72**.

In each of the unit circuits **U**, the PTC element **73** is connected in series to the resistance heating body **72**, and the resistor **74** is connected in parallel to the PTC element **73**. That is, the resistor **74** serves as a parallel circuit with respect to the PTC element **73**.

In the solid heater **71** according to the second exemplary embodiment, the resistors **74** may be formed simultaneously with the resistance heating bodies **72**, and no chip resistors such as metal-glaze resistors are necessary.

That is, the solid heater **71** according to the second exemplary embodiment is more easily manufacturable than the solid heater **71** according to the first exemplary embodiment.

The operation of the solid heater **71** according to the second exemplary embodiment is the same as that described in the first exemplary embodiment, and description thereof is omitted.

The foregoing description of the exemplary embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical

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applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents. 5

What is claimed is:

1. A heating device comprising:

a rotating member configured to rotate; and

a plurality of unit circuits that are aligned in a width direction of the rotating member, the plurality of unit circuits each including: 10

a heating body configured to heat the rotating member,

a resistive element having a variable resistance, the resistive element being connected in series to the heating body and having a positive temperature coefficient, and 15

a parallel circuit that is connected in parallel to the resistive element,

wherein the unit circuits are each configured such that:

at a first time, a percentage of heat generated by the heating body is greater than a percentage of heat 20

generated by the resistive element and greater than a percentage of heat generated by the parallel circuit,

at a second time, the percentage of heat generated by the heating body is less than the percentage of heat 25

generated by the resistive element, and

at a third time, the percentage of heat generated by the parallel circuit is greater than the percentage of heat 30

generated by the heating body and greater than the percentage of heat generated by the resistive ele-

ment.
2. The heating device according to claim 1, wherein, at a first temperature that is less than a second temperature, a resistance value of the parallel circuit included in each of the unit circuits is larger than the resistance value of the resistive 35

element, and at the second temperature the resistance value of the parallel circuit is smaller than the resistance value of the resistive element.
3. The heating device according to claim 1, wherein the rotating member is heated to a predetermined temperature 40

when a current flows through the parallel circuit in each of the unit circuits with a rise of a temperature of the resistive element.

4. A fixing device comprising:

a heating device that includes a rotating member configured to rotate, and a plurality of unit circuits that are aligned in a width direction of the rotating member, the plurality of unit circuits each including: 45

a heating body configured to heat the rotating member,

a resistive element having a variable resistance, the resistive element being connected in series to the heating body and having a positive temperature coefficient, and 50

a parallel circuit that is connected in parallel to the resistive element; and 55

a pressing member that is in contact with the rotating member heated by the heating body, the pressing member and the rotating member providing a nip part where each of a plurality of kinds of recording media having different sizes in the width direction is nipped, 60

wherein the unit circuits of the heating device are each configured such that:

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at a first time, a percentage of heat generated by the heating body is greater than a percentage of heat

generated by the resistive element and greater than a percentage of heat generated by the parallel circuit,

at a second time, the percentage of heat generated by the heating body is less than the percentage of heat

generated by the resistive element, and

at a third time, the percentage of heat generated by the parallel circuit is greater than the percentage of heat

generated by the heating body and greater than the percentage of heat generated by the resistive ele-

ment, and

wherein at least one of the unit circuits is provided at a position in an out-of-path area that is on an outer side of an area over which a smallest one of the recording media to be nipped in the nip part passes.

5. An image forming apparatus comprising:

a fixing device configured to fix a toner image to a recording medium, the fixing device including:

a heating device including a rotating member configured to rotate, and a plurality of unit circuits that are aligned in a width direction of the rotating member, the plurality of unit circuits each including:

a heating body configured to heat the rotating member,

a resistive element having a variable resistance, the resistive element being connected in series to the heating body and having a positive temperature coefficient, and

a parallel circuit that is connected in parallel to the resistive element, and

a pressing member that is in contact with the rotating member heated by the heating body, the pressing member and the rotating member providing a nip part where the recording medium is nipped, the recording medium being one of a plurality of kinds of recording media having different sizes in the width direction; and

a transporting portion configured to transport each of the plurality of kinds of recording media having different sizes in the width direction toward the fixing device, wherein the unit circuits of the heating device included in the fixing device are each configured such that:

at a first time, a percentage of heat generated by the heating body is greater than a percentage of heat

generated by the resistive element and greater than a percentage of heat generated by the parallel circuit,

at a second time, the percentage of heat generated by the heating body is less than the percentage of heat

generated by the resistive element, and

at a third time, the percentage of heat generated by the parallel circuit is greater than the percentage of heat

generated by the heating body and greater than the percentage of heat generated by the resistive ele-

ment, and

wherein at least one of the unit circuits is provided at a position in an out-of-path area that is on an outer side of an area over which a smallest one of the recording media to be transported by the transporting portion and to be nipped in the nip part passes.

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